1,4-dimethylnaphthalene
for use as a post-harvest adjuvant

Executive Summary[1]

The following petition is under consideration with respect to NOP regulations subpart G, governing the inclusion of substances on the National List of Allowed and Prohibited Substances:

Petitioned: **Addition of 1,4-dimethylnaphthalene (1,4-DMN) to section 205.601(k), "Synthetic substances allowed for use in organic crop production as plant growth regulators."**

1,4-dimethylnaphthalene (1,4-DMN) is a volatile plant organic compound that occurs naturally in potatoes. It may be extracted from potato skins, and in this case the substance is synthetically produced for use as a plant growth regulator. Specifically, the substance inhibits sprout formation and etiolated growth in stored potatoes, thus prolonging effective storage time while maintaining tuber quality. The effects of 1,4-DMN are reversible, and hence it can be used on seed potatoes in addition to processing and fresh market potatoes.

The TAP reviewers were divided over the use of 1,4-DMN on postharvest potato stores. Two reviewers feel it should not be added to the National List, while acknowledging its efficacy for the intended purpose. One feels that the existence of other organically approved alternatives precludes the need to add a synthetic to the List; the other reviewer feels that irrespective of the utility of a substance, the lack of full disclosure of manufacturing methods is enough to restrict its use. The third reviewer recommends allowance of the substance based on the lack of an equally effective, readily available substitute; the reviewer also indicates that such a recommendations relies on "key assumptions" regarding the toxicity of the precursors and proper use of 1,4-DMN.

Summary of TAP Reviewer Analyses

Synthetic/ Nonsynthetic	Allowed or Prohibited	Notes/suggested annotations:
Synthetic (3) *Nonsynthetic (0)*	*Allowed (1)* *Prohibited (2)*	***Reviewer 1:*** *Prohibited, no annotation.* ***Reveiwer 2:*** *Prohibited, no annotation.* ***Reviewer 3:*** *Allowed, no annotation.*

[1] *This Technical Advisory Panel (TAP) review is based on the information available as of the date of this review. This review addresses the requirements of the Organic Foods Production Act to the best of the contractor's ability, and has been reviewed by experts on the TAP. The substance is evaluated against the criteria found in section 2119(m) of the OFPA [7 USC 6517(m)]. The information and evaluation presented to the NOSB is based on the technical evaluation against those criteria, and does not incorporate commercial availability, socio-economic impact or others factors that the NOSB and the USDA may consider in making decisions.*

Identification

Chemical name:	1,4-dimethylnaphthalene	**CAS Number:**	571-58-4
Other names:	1,4-DMN; naphthalene, 1,4-dimethyl; naphthalene acetic acid	**Other:**	
		EPA Reg. Nos.	67727-1, 67727-3, 67727-4
		OPP Chemical Code	55802
Trade names:	1,4SIGHT, 1,4SEED, 1,4SHIP		

Characterization

Composition:
$C_{12}H_{12}$

Physical Data:

Molecular wt.:	156.2g/mol
Melting point:	N/A
Boiling point:	264°C
Specific gravity:	1.014
Solubility:	5.1ppm in H_2O
pH (1% solution @ 25°C):	5.9
Stability:	stable
Vapor Pressure (Pa):	0.56
Flammability:	122°C @ 760mm Hg

Properties:
1,4-dimethylnaphthalene (1,4-DMN) is an aromatic hydrocarbon that occurs naturally in potatoes (*Solanum tuberosum* L.). The pure extract is a pale yellow to colorless liquid, and smells of petroleum distillates.

Action:
The mode of action of 1,4-DMN is currently unknown. It is thought to mimic a natural potato sprout inhibitor hormone, but no research has substantiated this hypothesis (Lewis 1999).

How Made:
The petition states that "methods have been developed to produce 1,4-DMN in laboratory and manufacturing setting." Noting that 1,4-DMN can be extracted from natural sources, the Petitioner states that there are currently no suppliers who source 1,4-DMN in this way. The petition states, "The synthetic method produces 1,4-DMN chemically identical to the isomer as found in nature, but in larger quantities." The manufacturer claims manufacturing processes as confidential business information (CBI) and does not explicitly state the methods of production.

Uses:
1,4-DMN is used as a plant growth regulator to inhibit sprouting of potatoes during storage and shipping. It is commonly applied in closed storage areas as a thermal (heated) aerosol fog. The substance has no other known practical applications.

Status

History of Use:
The use of volatile plant compounds in post-harvest potato storage is an ancient concept. For centuries, South American Incas used leaves of muña, a selection of plants rich in monoterpene-containing oils, to prevent sprouting and disease in potatoes stored in earthen storage pits (Vaughn & Spencer 1991). One of the first modern examinations of sprout inhibitory activity indicated that storage of ethylene-emitting apples with potatoes inhibited the normal growth of tuber sprouts (Elmer 1932). Ethylene has also been shown to have inhibitory and promotive effects on sprouting, depending on treatment regime and whether exposure is continuous or intermittent (Hughes et at. 1973; Rylski et al., 1974; Metlitskii et al. 1982; Timm et al 1986; Prange et al 1988). Over time, many naturally occurring volatile biochemicals have been identified that evolve from stored potatoes, some of which appear to increase the dormancy period. Subsequent research has revealed that several isomers of dimethylnaphthalene (DMN), which occur naturally in potato skins, have sprout-inhibiting effects (Meigh et al. 1973). Beveridge (1981) further evaluated the ability of 1,4- and 1,6-DMN to act as a potato sprout suppressant in seed tubers, followed by Filmer and Rhodes (1985) who confirmed the superior efficacy of 1,4-DMN compared to other naphthalenes produced by potatoes.

The use of 1,4-DMN has gained limited acceptance in Europe and some parts of India, while the vast majority of conventional growers worldwide continue to rely on the chemical isoproyl-3-chlorophenylcarbamate (CIPC) for sprout suppression (Burton 1992) (see below). Synthesized 1,4-DMN has no history of use in organic systems.

Functionality

All potato varieties have a natural dormancy period that varies according to specific cultivars. Beyond that time period, sprouting becomes a major cause of losses in stored potatoes. In addition to reducing the number of marketable potatoes, development of sprouts can dramatically decrease potato weight through both evaporative and dry matter losses (Burton 1992; Plissey 1992). This is especially true in colder climates, which comprise the majority of organic potato cultivation acreage but are limited by a short growing season and prolonged storage (USDA 1997). Because the potato harvest period in these areas is relatively short, sales during the off-season are dependent on a supply of stored tubers. According to the Petitioner, "A full 90% of the potatoes produced in the US are harvested in the fall, with the remaining 10% of the varieties reaching maturity during the winter, spring, or summer. Nearly half of all potatoes in the US are placed in storage facilities, so that the potato crop can be released throughout the year to the fresh market and processed food industries." In the absence of a sprout suppressant, organic producers must harvest continuously in order to offer quality potatoes throughout the year, an impossibility for the majority of growers. Hence, not having a consistent source of organic crop restricts organic growers from fully integrating into processed food markets. According to the Petitioner, "Organic growers are confined to relying on a few varieties which allow limited storage, and then use physical means to detach sprouts when potatoes are removed from storage."

In terms of short-term viability, careful management of environmental conditions of storage such as temperature, humidity, and ventilation, are necessary to maintain a quality post-harvest crop (Walsh 1995). Decreases in atmospheric oxygen ([O_2/CO_2]) were found to suppress sprouting (Prangue *et al* 1997). However, high [CO_2] can result in a physiological defect know as black heart (Afek and Warshasky 1998). Aside from sprout suppressants, storing at low temperatures (3-7°C) is the most common method of prolonging potato dormancy (Khanbari and Thompson 1996). However, long-term storage at low temperatures adversely affects quality. Low temperatures cause the degradation of starch to sugar, increasing tuber sweetness (Es and Hartmans 1987; Morell and Rees 1986; Rees *et al*. 1981; Ross and Davies 1992). High reducing sugar levels, in turn, cause potato pulp to turn dark when fried. This is of significant concern for potatoes intended for processing markets, where the most important aspect of quality is color (Walsh 1995).

The Petitioner requests that 1,4-dimethylnaphthalene be approved for use as a plant growth regulator (§205.601(k)). Specifically, products containing 1,4-DMN would be applied to post-harvest potatoes in closed storage areas to enhance dormancy and suppress sprouting. Whereas cultural controls are most effective in the short term, "potatoes treated with 1,4-DMN can be stored for up to one year with no change in quality. If 1,4-DMN is made available to organic potato growers, they will not only be able to penetrate the processed food market, they will be able to successfully compete with the general potato grower by offering high quality organically-produced potatoes throughout the year" (Petition). In addition, the effects of 1,4-DMN are fully reversible, which allows it to be used on potato seed crops as well as in processing and fresh markets.

OFPA, USDA Final Rule

The OFPA does not mention 1,4-dimethylnaphthalene. The USDA Final Rule has no guidelines governing the use of 1,4-DMN specifically or potato sprout inhibitors in general.

Regulatory:

Domestic organic certifiers including **CCOF, QAI, NOFA** (all chapters), and **Oregon Tilth** all defer to the NOP National List, which has not ruled on the use of any potato sprout suppressants.
Japanese Agricultural Standards (JAS) does not permit the use of 1,4-DMN.
FAO Codex Alimentarius does list 1,4-DMN as an allowed substance.
IFOAM explicitly prohibits "nature identical" substances in food, which would include "synthesized" 1,4-DMN.
EPA classifies 1,4-DMN as a biochemical as defined by 40 CFR 158.65. It is further identified under Para-4C as a pretreatment pollutant needing further study.
FDA EAFUS Food Additive database does not reference 1,4-DMN.
NIEHS National Toxicity Program (NTP) Database does not reference 1,4-DMN.
OSHA does not classify 1,4-DMN.
International Agency for Research on Cancer (IARC) has not evaluated 1,4-DMN.

Processing Criteria from the February 10, 1999 NOSB Meeting

1. ***The processing aid or adjuvant cannot be produced from a natural source and has no organic ingredients as substitutes***

   1,4-dimethylnaphthalene occurs naturally in potato skins and was first isolated by Meigh (1973). If approved by the NOSB, however, the Petitioner intends to market 1,4-DMN produced in a laboratory setting. The Petition states, "While 1,4-DMN naturally occurs in vegetables, the cost involved in extraction methods make it unfeasible to rely upon extraction to produce the commercial quantities. As 1,4-DMN is efficacious at relatively low levels, it is correspondingly available in only small amounts in individual plants and tubers. Therefore, methods have been developed to produce 1,4-DMN in laboratories and manufacturing settings in sufficient quantities for commercialization. The synthesized 1,4-DMN is chemically identical to the compound as it naturally occurs."

   As noted in "History of Use" (*above*), the use of volatile plant compounds in post-harvest potato storage is not a recent development. Beveridge (1981) studied 20 volatile organic compounds as sprout suppressants. Several come from natural sources: citral, camphene, citronellol, naphthalene, coumarin, limonene, carvone, pulegone, camphor, and vanillin, to name a few. Among these, *S*-(+)-carvone (derived from caraway seed extract, *Carum carvi*) and 1,4-DMN have been studied extensively to ascertain their efficacy as sprout suppressants (Brown *et al*. 2000; Kerstholt et al. 1997; Brown *et al.* 2000; Boylston *et al.* 2001; Oosterhaven *et al.* 1993). Much of this research has been aimed at finding an economical, effective, and more natural alternative to the use of isoproyl-3-chlorophenylcarbamate (CIPC), a widespread, synthetic, conventional sprout suppressant. A study by Baker and his colleagues (2000) showed that 1,4-DMN applied at 60ml t^{-1} and carvone at 600ml t^{-1} were as effective as CIPC applied at commercial rates, with no discernible loss in processing quality. The same researchers showed that plants grown from potato seed tubers treated with carvone produced more vigorous plants and higher yields than those treated with 1,4-DMN (Brown 2000).

There is also a desire among the potato seed industry to develop a sprout inhibitor that is reversible (Sorce *et al.* 1997). Chemical sprout suppressants such as CIPC have a long-term inhibitory effect that, if applied to a seed crop, would render it useless. In contrast, carvone and 1,4-DMN do not permanently inhibit the tuber from sprouting and thus they can be used on potato seed crops (Lewis *et. al* 1997). In Europe, some countries have effectively disallowed the use of CIPC (Lodewijk 1994), and the anti-sprouting activity of carvone is now replacing synthesized chemicals largely due to its reversible character (Capelle 1996).

Talent®[2] is currently the only commercial sprout suppressant formulation that uses carvone as its primary active ingredient. However, Talent has not been evaluated for organic production and thus is not available to the US organic industry. Despite its effectiveness and increasing popularity in European markets, the present formulation is not allowed by IFOAM. It appears that, much like 1,4-DMN, the questionable sourcing and laboratory formulation of Talent® would require a formal TAP review before a decision could be made about its acceptability.

Aside from the volatile organic compounds mentioned above, there is at least one registered potato sprout suppressant that is agricultural-based, OMRI approved, and currently in use. Biox A®[3], or eugenol, is a technical grade clove oil extract applied as an aerosol mist. According to initial reports from one potato producer, the product is highly effective at "burning" newly emerged sprouts even at twice the recommended application interval (personal communication). Preliminary evaluations at the University of Idaho have shown Biox A® treatments may be as effective as CIPC in suppressing sprouts on Russet Burbank potatoes (Kleinkopf, unpublished). In addition, UC SAREP has located an organic potato producer who has developed independently a sprout suppression product likely derived from a combination of clove and/or peppermint oils. The grower currently has a patent pending on the substance, and would not provide more specific information on its formulation. However, they report similar success as the grower using Biox A®, with little to no impact on taste or processing quality (personal communication). Both growers commented on the presence of residual odors when the tubers are removed from storage, but stated that this had not adversely affected their marketing choices.

2. ***Manufacture, use, and disposal do not have adverse effects on the environment and are done in a manner compatible with organic handling as described in section 6513 of the OFPA***

<u>NOP report:</u>[α] 1,4-DMN is completely synthesized from two precursors in a multistep batch process. The two DMN precursors are synthetic substances and are included in EPA databases. Both precursors are organic (in the chemical sense) significantly capable of interacting with other chemicals present in the soil, especially petroleum based products. EPA has database information on programs which monitor the two DMN precursors. These programs appear to be based upon the need to quantitative environmental impact and persistence. The establishment of EPA monitoring programs for both DMN precursors suggests significant potential for environmental contamination. The impact on soil organisms is at this time undetermined, however, both DMN precursors appear to impact the biochemistry of organisms. DMN Precursor 2 is approved for use in fungicide applications by the EPA.

The Petitioner currently holds a patent on synthesis of 1,4-DMN, and claims specific information relating to the manufacturing of this substance as confidential.

Pursuant to the registration of 1,4 SIGHT®, 1,4-DMN was evaluated for the following environmental toxicity effects:
<u>Avian studies</u> showed that the acute oral LD_{50} value for northern bobwhite quail (*Colinus virginianus*) exposed to naphthalene was >2000mg a.i./kg. The no observed effect level (NOEL) dosage was 2,000mg a.i./kg. The results indicate that naphthalene should not cause any adverse effects to avian wildlife (Ahmed 1993).
<u>Fish studies</u> on rainbow trout (*Oncorhynchus mykiss*) gave an acute 96 hour LC_{50} of 0.67mg a.i./L. The 96 hour NOEL was 0.19mg a.i./L. The results indicate that naphthalene is highly toxic to freshwater fish species and would likely cause adverse effects if managed inappropriately (Bettencourt 1993).

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[2] BV Luxan, Elst, The Netherlands
[3] Xeda Americas, Riverside, CA, USA
[α] This information is an evaluation of confidential business information (CBI) supplied by the NOP. NOP policy for handling CBI in National List petitions requires USDA staff to evaluate the information vis-à-vis OFPA criteria and forward this information to the contractor for incorporation into the TAP report. The information pertains only to the substances used to manufacture 1,4-DMN. UC SAREP has chosen to reprint all information obtained from the NOP verbatim.

Aquatic invertebrate studies on daphnids (*Daphnia magna*) determined a 48 hour EC_{50} of 0.54mg a.i./L, with a NOEL of 0.10mg a.i./L. This data indicates that naphthalene is highly toxic to aquatic invertebrate species and would likely cause adverse effects if managed inappropriately (Putt 1993).
Mammalian wildlife studies have not been performed outside of the data collected in human toxicity tests (*see Criteria 3, below*). That data, based on acute oral testing of rats at the maximum hazard dose, indicate the risk to mammalian life is expected to be minimal to non-existent (Pilsucky and Leovey 1994).
Nontarget plant species studies are conditionally required by the EPA when there is published evidence that a compound is toxic to plants. The contractor found no information evaluating the toxicity of 1,4-DMN to plants.

The substance is applied via a thermal aerosol fog in a closed storage area, and will not escape these areas in potentially deleterious amounts if managed appropriately. 1,4-DMN is a volatile biochemical, and is gradually biodegraded by the potato or dissipates into the surrounding atmosphere. Hence, "disposal" presents little chance for environmental contamination.

3. ***The nutritional quality of the food is maintained and the material itself or its breakdown products do not have adverse effects on human health as defined by applicable Federal regulations***

Acute toxicity / EPA Classification, Toxicity Category:

Oral LD_{50} =	2730 mg/kg (rat) / ACCEPTABLE, III (Johnson 1993)
Dermal LD_{50} =	>2 g/kg (rabbit) / ACCEPTABLE, III (Johnson 1993)
Inhalation LD_{50} =	4.16 mg/L (rat) / ACCEPTABLE, IV (Rajendran 1993)
Eye irritation	Moderate in all rabbits at 24 hours after administration, irritation dissipated by day 21 / ACCEPTABLE, II (Johnson 1993)
Dermal irritation	Moderate in rabbits at 0.5mL dose; irritation dissipated by day 14 / ACCPETABLE, IV (Johnson 1993)
Skin sensitization	Not apparent in guinea pigs (modified Bueller method) / ACCEPTABLE (Johnson 1993)

Mutagenicity assays:

AMES	96.4% pure 1,4-DMN, in the presence or absence of metabolic activation homogenate, is not a mutagen for any *S. typhimurium* strains tested / ACCEPTABLE (Lawlor 1993).
DNA synthesis	The test material did not appear to induce nuclear grain counts at the tested concentration range of 0.25µg/mL. 1,4-DMN is inactive in the in vitro test for unscheduled DNA synthesis in rat liver primary cell culture / ACCEPTABLE (Ham 1993).
In-vivo micronucleus	1,4-DMN did not increase the number of micronuclei per 1000 polychromatic erythrocytes in the bone marrow of the CD-1 mouse at does of 225 mg/kg, 450 mg/kg, and 900 mg/kg / ACCEPTABLE (Murli 1993).

As stated above, the mode of action if 1,4-DMN is not known; it likely acts similar to the naturally produced plant hormone. Because the substance is a naturally occurring compound already present in potatoes, it application should not be expected to affect the nutritional quality of the product when the substance is used appropriately.

NOP Report: DMN Precursor 1 is considered to be a respiratory irritant with significant exposure and has other nonlethal effects on human health. The evidence in [sic] inconclusive if this substance is a carcinogen. However, DMN Precursor 2 is included on the National Institute for Occupational Safety and Health (NIOSH) carcinogen list. It is [sic] also been shown to effect reproductive systems.

4. ***Its primary purpose is not as a preservative or used only to recreate/improve flavors, colors, textures, or nutritive value lost during processing except in the latter case as required by law***

Webster's New Collegiate Dictionary (9th ed.) defines *preservative* as "an additive used to protect against decay, discoloration, or spoilage." Functionally, the primary purpose of 1,4-DMN is to inhibit etiolated growth and thus lengthen the effective storage time and marketability of potatoes. In this way, the substance appears to fit the definition of a preservative. However, given that the compound is analogous to a naturally occurring plant growth regulator, and as such it serves a physiological function that is inherent in the life cycle of some plants, the substance may not be considered a preservative in a conventional processing sense. By way of comparison, ethylene also acts as a plant growth regulator in much the same manner, and its synthetic analog is approved for conditional use in organic production (§205.601(k)) and processing (§205.605(b)(10)).

5. ***It is Generally Recognized as Safe (GRAS) by FDA when used in accordance with Good Manufacturing Practices (GMP) and contains no residues of heavy metals or other contaminants in excess of FDA tolerances***

The substance is listed under 40 CFR180.1142, exempting it from the requirement of tolerance when applied post harvest to potatoes in accordance with GMPs. The exemption is based on its classification as a naturally occurring biochemical (EPA 1995).

6. Its use is compatible with the principles of organic handling.

NOP Report: Given the EPA monitoring programs and impacts on human health, DMN Precursor 1 and DMN Precursor 2 appear not to be compatible with sustainable agriculture.

1,4-DMN is applied in closed storage areas as an aerosol fog by means of an aerosol generator. The liquid is sometimes heated to decrease its viscosity. The volatile nature of the substance aids in ensuring good distribution of the substance throughout the pile, provided that storage areas have recirculating air systems. In the cases of the two substances already in use as organic sprout suppressants (see Criteria 1), these application methods have been examined and approved by regional certifiers. Since 1,4-DMN is applied in the same fashion, its use is likely to be compatible with a grower's Farm Plan.

7. There is no other way to produce a similar product without its use and it is used in the minimum quantity required to achieve the process

The Petitioner currently markets three proprietary sprout suppressant formulations that contain 1,4-DMN as the active ingredient, each of which has different application rates.[4] The master label for 1,4-SIGHT® recommends application levels up to 1 pound of active ingredient per 50,000lbs product, or 20ppm per potato. Since the substance is volatile, it gradually dissipates after application. Kalt and others (1999) observed substantial sprout development when 1,4-DMN was applied at the recommended rate for commercial storage, and higher application rates were suggested. In one study, effective rates were achieved at 40-80ppm, with concentrations dropping to 50ppb after sixteen weeks (Boylston 2001). Knowles (2002) found that 1,4-DMN concentrations decreased rapidly following application, and reapplication was necessary after one month to maintain sprout suppression effects. Maximum efficacy occurred when application closely coincided with the end of a potato crop's natural dormancy period.

Because DMN is naturally occurring in the potato, it is exempted from tolerance by the EPA (i.e., no minimum amount of residue on potatoes has been established)[5] which could lead a user to over-apply. However, its effectiveness at relatively low concentrations makes this unlikely. Seed growers have an added disincentive to over-apply, since any residuals could act to delay sprouting longer than intended.

Historically, there have been no commercially available organic sprout suppressants, leaving the industry to rely on atmospheric controls to delay sprouting (Prangue *et. al*, 1997; Rastovski 1987). In evaluating the use of some volatile organic compounds as alternative sprout suppressants, Beveridge and his colleagues (1981) proposed several key properties:

- The chemical should inhibit sprouting under commercial storage conditions and at low concentrations
- It should be suitable for use on seed potatoes (i.e., it should be reversible) and have minimal effects on their subsequent performance
- It should be volatile
- It should be equal to or better than any commercial alternative

Kalt et al. (1999) expanded on this, stating that the commercial feasibility of inhibitors will be influenced by the total cost per storage season, special storage needs (e.g. atmospheric controls), application costs, and processing quality after storage. Management of stored potatoes also varies depending on the intended market. Table, seed and processing potatoes have specific requirements that affect storage management techniques, which in turn affect long term storage viability. Lastly, the extent of sprout suppression is highly cultivar-dependent, and the timing of application and initial headspace concentration are critical in regards to efficacy (Baker *et. al* 2000).

As mentioned in Criteria 1, there appear to be several potential alternatives to the use of 1,4-DMN. Cineole (the primary aromatic compound in eucalyptus) and salicylaldehyde are effective suppressants, but unlike 1,4-DMN their residues can be tasted, making them unsuitable for commercial production (Boylston 2001). Carvone, the main compound in essential oils derived from caraway (*Carum carvi*), has been investigated extensively and is one of the only commercially developed alternatives to CIPC besides 1,4-DMN. Irrespective of concentration, carvone applied as a powder, or dill and caraway seed extracts applied as an emulsion effectively suppressed sprout growth in Norland potatoes for about six weeks and in Snowden potatoes for about sixteen weeks (Tanino *et. al*, no date). Carvone also inhibited Monalisa potato sprouts for eight weeks (Sorce *et al*. 1997). In addition, carvone possesses antifungal and antibacterial properties that protect against several storage diseases (Hartsman, *et al.* 1995; Oosterhaven, *et al.* 1995), and field slugs (Ester and Trul 2000). However, its use by the US organic industry may be restricted under its current formulation.

There also appears to be potential for agricultural-based, non-proprietary sprout inhibiting substances that qualify as organic materials. According to the NOSB, any naturally-occurring substance that is a by-product of a living organism is a de facto organically approved substance, and should not be added to the National List (NOSB 2002). At least two such substances are currently in use for potato sprout suppression (see Criteria 1). In addition, menthone and neomenthol vapors (prepared

[4] It should be noted that much of the information provided by the petitioner, such as EPA toxicity reports and application rates, refer to the use of 1,4-DMN in the product 1,4SIGHT, a formulation containing a certain percentage of undisclosed inerts. Experimental research on 1,4-DMN has also tended to use this formulation, or the pure substance. This report evaluates 1,4-DMN only, and not the three DMN formulations referenced in the petition.

[5] See *Criteria 5*, above

from *Mentha spp.*) were recently found to gave complete sprout suppression in nondormant Russet Burbank tubers and were five times more effective than carvone when applied together (Coleman *et al.* 2001). While initial results seem positive, more research is needed to determine how residual odors from these substances may affect marketing choices.

Increasing public concerns about the use of CIPC – a non-reversible, widely used chemical suppressant – have led to an interest in developing alternative sprout inhibitors (Lewis *et al*. 1997), of which 1,4-DMN has proven to be safe and very effective. The ongoing effort to replace CIPC provides an incentive to continue researching the efficacy of other alternative sprout inhibitors, some of which will be automatically eligible for certified organic status.

TAP Reviewer Discussion

Reviewer 1 *[Production manager and organic crop advisor, fourth generation family farmer, 30 years potato cultivation experience with 16 years in organic vegetable production, Pacific Northwest]*

My experience with potatoes goes back to the late 1960's when my brother grew fresh market Russets for local markets. I did the same for FFA in 1975, and again in 1983. In 1985 we converted to organic production. I remember as a child helping my mom break sprouts off our table spuds in late spring, as our 1870 stone cellar wouldn't hold down temperatures past April. I have seen enough potato sprouts to give most people nightmares, and the thought of an organic sprout control is truly a wonderful idea.

My primary sprout control technique in the past was to hold the storage temperature as low as possible (mid 30's). This did of course convert starch to sugar, but all my fresh market customers liked my "sweet potatoes". The tubers sprouted quickly when taken out of refrigeration, and I solved the problem by insisting to stores that they keep them in a cooler and advising retail ustomers to keep them refrigerated. My storage cellar would delay sprouting on most of the varieties through April with only natural ventilation. Refrigeration beyond that period would have extended this at least another month, maybe two.

Since coming to [*deleted*] Farms, I have overseen cultivation of organic potatoes for processing into french fries, hash browns, and tator tots. In 2000 and 2001 we had over 3,000 tons of Rangers and Umaillas. The Rangers were processed for fries directly out of the field and the Umatillas went into storage at 46°F. In 2001 we also stored some of the Rangers for a couple of months before processing. At 46°, we pretty much had to use the Umatillas by March or the sprouts became a problem. In 2001, after the Rangers came out we lowered the temp to 42°. This worked for a while, but the Umatillas started sprouting in late January even at 42°.

Around the same time, I had been in contact with Frazier and Brant at the University of Idaho, Kimberly, about storage temperature and sprout control. Both have tested mint and clove oil for sprout control, with notable success. One clove oil formulation, "Biox A", had just received OMRI listing, and we became the first commercial user of the product.

[A regional agrochemical] distributor… in [the Pacific US] had [a regional chemical applicator]… in [the Pacific US] apply Biox to 1,800 tons of our Umatillas in storage. At the time of application we had 1" to 4" sprouts, and Biox completely stopped all sprout growth for over a month. When they started peeping again about 5-6 weeks later, we hit them again and it burned all the new tips. Again, they didn't start again for another month. Biox also seemed to suppress rot in the pile as well. [The applicator] commented on how well the Umatillas held up compared to others potato stocks he took care of. If we had treated when the sprouts first peeped and kept treating, we would have had great control. The cost was more then CIPC, but [the applicator's] expertise brought costs down some. The clove odor was noticeable but didn't persist after the washer. All things considered, Biox is a great breakthrough and we will continue to use it. Mint oil and probably jasminates and others also control sprouts.

In terms of 1,4–DMN, it sounds too good to be true: a natural dormancy enhancer that can also be used on seed potatoes – just quit treatment and they sprout like normal. Everyone has to agree this would be great, and it would be if you could extract commercial quantities from natural sources. As for the petition to allow 1,4–DMN in organic production: does the end (great sprout control), justify the means (approval of a synthetic product)? As much as I would like to have this tool to use, I cannot justify this synthetic material in organic production. I would have come to the same conclusion without Biox or mint oil, even if they were less effective or were more costly.

The petition states that 1,4–DMN is the only alternative to CIPC. This is not true. It states that the synthetic form is identical to the natural. Maybe it is, maybe it is not. (Are the residuals and breakdown byproducts identical as well?) It also states that organic growers have no options for biochemical sprout control. Again, this is not true. Biox may not suppress spuds for a full year; but by the time the stored Northern spuds have to be used, the fresh crop from [Southern California] and other Southern growing regions are on the market.

As for the statement that there is little chance of environmental contamination since it used inside a closed storage area; anyone who has seen CIPC, 1,4Sight, or Biox treatment of a stored potatoes can tell you that it comes out of every single crack or crevice in the entire building, sometimes in quantities that make it impossible to be downwind of the building during application.

[*Deleted*] Farms and others have already more then "penetrated" the processed potato market without excessive difficulty. Biox has simply made this easier than it has been in the past. Potatoes can be processed into french fries all winter into spring and stored frozen for longer storage. Spuds processed for tater tots, hash browns and other forms can use cooler temps. Fresh market can use cooler temps that will usually hold until the Southern crop comes on. Processing potato chips is a bit more of a challenge, but you can hold organic chippers through March, maybe April with Biox.

Concluding remarks
Considering that the organic industry now has options for natural sprout control products, I cannot endorse approval of synthetic 1,4-DMN. Without Biox or mint, this would have been a little more difficult decision, but I still could not advise approval of a synthetic product for organic use. Please go back to the lab and find a cost effective way to extract the naturally occurring 1,4-DMN.

Recommendations to the NOSB:
a) The substance should be considered **synthetic** under the Final Rule.
b) The substance should be **prohibited** for use as a plant growth regulator in organic postharvest handling.

Reviewer 2 *[PhD, plant pathology; extension specialist; specializing in identification and control of postharvest decay and quality reduction factors in storage and transport of fresh market vegetables, Western US]*

Evaluation of Substance
The technical review provided is substantially complete and this reviewer is not aware of additional substantive information. Additional studies or grower-empirical tests on sprout retardation have been done with thermal fogs of concentrated hydrogen peroxide or mixtures of peppermint and spearmint oils and eugenol. Hydrogen peroxide appears to be effective but suffers the limitation of being a "burning" agent rather than a cell expansion retardant. Long-term storage, the desired benefit delivered by 1,4 DMN, may result in excessive quality and weight loss.

Compatibility with the Principles of Organic Handling
Within the information provided, the synthesis and formulation of surrogate 1,4 DMN does not appear to be consistent or compatible with the principles currently applied to the permissibility of substances selected for organic postharvest handling and processing. The fact that the plant responds as if the naturally derived biochemical was functioning has not been a sufficient and compelling criterion within the review of other natural process mimics. In contrast, the inclusion of catalytically evolved ethylene (the surrogate for a natural plant hormone) as an agent for ripening or color-conversion, is permitted due to the recognized compatibility of precursor materials and the well-defined process. Although this reviewer does not have any concerns for the safety or secondary and non-target effects of 1,4 DMN, as proposed, concern arises from the potential precedent set for allowance of derivative biologically active formulations from diverse technologies. The guidelines and principles of permissible processes and standards of need for the organic industry must be addressed first. For example, many highly useful natural, bioactive compounds for pest management and postharvest quality management could be more economically and consistently produced for use by the organic industry by recombinant technologies. These mimics and surrogate biochemicals could readily increase broader adoption of organic farming and processing practices and increase market penetration. To date, the application of biotechnology, even for highly purified proteins and enzymes, has been regarded as inconsistent with the principles of organic handling.

Alternative Methods of Economically Viable Sprout Suppression
The reviewer is not aware of any sufficiently suitable or economically practical alternatives that would achieve the benefits of 1,4 DMN treatment, beyond those alternatives discussed in the technical information provided. Storage environmental management can achieve short-term storage objectives but sprout suppression by controlled atmosphere and strict temperature regulation is difficult to implement. Significant capital investment would be required and substantial risk of quality reduction or loss would be expected for anyone attempting to scale-up storage capacity to expand organic potato markets.

Summary Determination of Reviewer
1,4-dimethylnaphthalene (1,4 DMN) should not be listed as an allowed substance for postharvest application to potatoes due solely to the non-disclosure of the process of formulation. Treatment of potatoes with 1,4 DMN would be highly likely to provide a very positive benefit to shippers and marketers of organically produced and handled potatoes, expanding current channels of commerce and opening new markets. No other reversible, sprout-inhibitor has the demonstrated efficacy and practical potential of 1,4 DMN for the organic industry. Nonetheless, it is the opinion of this reviewer that listing this substance as allowable is not consistent with the principles and expectations of the supporters of organic methods of production and postharvest processing. Unless the National Organic Standards Board (NOSB) is prepared to establish a precedent of permitting natural compound mimics and surrogates, derived by an undisclosed process, in general or by exemption for special need, 1,4 DMN must be listed as prohibited, at this time.

Recommendations to the NOSB:
a) The substance should be considered **synthetic** under the Final Rule
b) The substance should be **prohibited** for use as a plant growth regulator in organic postharvest handling.

Reviewer 3 *[PhD, soil fertility, plant physiology; extension vegetable specialist; career specialization in potato research, Western US]*

NOSB Processing Criteria Evaluation

1. *It cannot be produced from a natural source and has no organic ingredients as substitutes*
This product cannot be, practically, produced from a natural source, despite the fact that it does occur naturally in small quantities in potatoes. The criterion that "no organic ingredients as substitutes"is less easily discerned. In fact, other sprout inhibitors are registered for use as organic sprout inhibitors on potatoes, including the use on seed potatoes. One key is the interpretation of "substitute." Just because more than one chemical is registered for similar uses, they may not substitute perfectly for one another. One may be more efficacious under certain circumstances – not easily defined – while another more effective under other situations. The substance, carvone, is also equally effective as 1,4-DMN, and equally reversible. It, however, is not registered either. Furthermore, implicit in "substitute" is the assumption that it is "available." Biox A is registered for the same purposes as proposed for 1,4-DMN. However, no comparative research studies are apparently available to determine the relative effectiveness. The availability of Biox A is also not documented. My perception is that its availability to organic potato growers is probably quite limited. Thus, my evaluation of this criterion is that 1,4-DMN does qualify for registration using this criterion of 1) "cannot be produced from a natural source" and 2) "has no organic ingredients as substitutes." If documentation can be supplied that bonafide research studies have shown equally applicability and equal effectiveness, and that Biox A is widely available to farmers throughout the U.S., then the conclusion must be that 1,4-DMN does not qualify. In the absence of both of those, it does qualify.

2. *Its manufacture, use, and disposal do not have adverse effects on the environment and are done in a manner compatible with organic handling as described in section 6513 of the OFPA*
During its manufacture, since precursors 1 & 2 are toxic, and DMN itself has some toxicity, the potential adverse effects on the environment, and on humans, must be seriously considered. Apparently, little risk exists during its use. And, since at least one of the precursors has been approved by EPA for use in fungicide applications, my interpretation is that 1,4-DMN probably qualifies under this criterion. The concern is the extent of risk in cases where management of the substance is not adequate during application. Further research addressing this issue should be conducted regardless of the final decision on [inclusion on the National List].

3. *The nutritional quality of the food is maintained and the material itself or its breakdown products do not have adverse effects on human health as defined by applicable Federal regulations*
The evidence to prove, or disprove, this criterion is weak. Toxicity studies indicate this substance poses little risk for adverse effects on human health, despite the potential risks of the precursors. No evidence is presented, however, concerning "the nutritional quality". The major components of "nutrition" include chemical composition (e.g. vitamin, carbohydrate, mineral, etc. concentrations), aesthetic qualities (appearance, turgor, color, taste, etc.), and ingestibility/digestability. Although, it can be inferred from the studies by Baker and others, that appearance and turgor are not obviously affected, taste and the chemical components have apparently not been addressed. The conclusion that, "Because the substance is a naturally occurring compound already present in potatoes, its application should not be expected to affect the nutritional quality of the product…" is not a valid conclusion. For example, another naturally occurring substance in potatoes is solanine, a glycoalkaloid that when present in concentrations above 15-20 mg / 100 g DW causes a very bitter taste and can cause stomach pain and nausea; certain storage conditions can result in an increase in TGA (total glycoalkaloids) in potato tubers. However, in spite of these concerns, my interpretation is that 1,4-DMN probably qualifies with this criterion.

4. *Its primary purpose is not as a preservative or used only to recreate/improve flavors, colors, textures, or nutritive value lost during processing except in the latter case as required by law*
1,4-DMN qualifies under this criterion. I concur with the analyses presented to me by UC SAREP.

5. *It is Generally Recognized as Safe (GRAS) by FDA when used in accordance with Good Manufacturing Practices (GMP) and contains no residues of heavy metals or other contaminants in excess of FDA tolerances.*
Appears to be consistent with the requirements of this criterion.

6. *Its use is compatible with the principles of organic handling.*
This criterion presents a difficult hurdle for 1,4-DMN. As discussed under No. 2 above, the potential environmental and human health risks of the Precursors 1 & 2, and possibly of 1,4-DMN itself (if not used properly) makes qualification under this criterion questionable. If registration approval is based on the assumption that correct management by the user is expected, 1,4-DMN should be approved. If the manufacturing process is considered a major factor in "…the principles of organic handling", then the request should be denied.

7. *There is no other way to produce a similar product without its use and it is used in the minimum quantity required to achieve the process*
The difficult component of this criterion to evaluate is "…no other way to produce a similar product…" As discussed under criterion No. 1, the question is whether or not currently registered substances are "similar" or "substitutes."

Research appears to support that the recommended rates are minimal and additional applications are optional, depending on the intended use and variety. Given the vagueness and uncertainty about competing substances, my recommendation is that 1,4-DMN satisfies this criterion.

Concluding remarks
The following positive recommendations are based on the assumptions detailed in the above discussion of the individual criteria. If any of those assumptions is incorrect, my recommendation for 2 and 3 would change. The key assumptions relate to interpretation of "substitute", the importance of the toxicity of the precursors, and the importance of "if properly managed during use."

Recommendations to the NOSB:
a) The substance should be listed as a **synthetic** on the National List
b) The substance should be **allowed**, for use as a plant growth regulator in organic postharvest handling.

* * *

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